The NASA "Why?" Files
The Case of the
Challenging Flight

Segment 3

The tree house detectives are closing in on the four forces of flight. To learn more about weight and the center of gravity, they visit an electronic classroom to connect with NASA Dryden Flight Research Center. The information they learn from Dryden helps them place their wings in the optimum position for flight. The tree house detectives are amazed when they learn how a computer enables a plane, the X-29, to fly with wings that are placed on "backwards!" Dr. D helps the tree house detectives understand Newton's first law of motion, and they begin to study the force of drag. They discover that nature is the key to understanding drag as they discuss "Biomimetics" with Ben Anders and learn how birds, insects, sharks, and other animals have aided in our knowledge of flight. The tree house detectives make a final stop at the NASA Langley Research Center to learn how new "smart" materials and composites reduce both drag and the weight of the plane. The tree house detectives realize that they must reduce the weight of their plane if they want to win the contest.

Objectives

The students will
• learn how weight and the center of gravity affect stability.
• understand Newton's first law of motion.
• discover how nature is the expert in reducing drag.
• learn that the weight of an airplane affects lift and drag.

Vocabulary

air resistance - a type of drag that occurs as an object moves through the air

"biomimetics" - the study of how birds, insects, and marine animals overcome drag

center of gravity - distribution of weight around a balance point

composite - usually refers to a type of structure made with layers of fiberglass or fiberglass-like materials such as carbon fiber

electronic classroom - a classroom using two-way audio and video communications over telephone lines

friction - force that opposes the motion of an object

Newton's first law of motion - an object at rest will remain at rest and an object in motion will remain in motion at a constant velocity unless an unbalanced force acts upon it

range - maximum flight distance

rudder - the primary control surface in yaw, it is usually hinged and attached to the trailing edge of the vertical stabilizer on an aircraft's tail.

Video Component (15 min.)

Before Viewing

1. Briefly summarize the events in Segment 2.
2. Review the forces of thrust and lift. Ask students to draw an illustration of how lift is created according to Bernoulli's principle.
3. Introduce the vocabulary for Segment 3.
4. Compose a list of living things that fly and a list of those that do not fly. Compare and contrast the animals/insects. Discuss why some birds do not have the ability to fly. Discuss adaptations for flight and how an animal's environment supports these adaptations.
5. Review the process of scientific inquiry. Ask the students to identify the steps that the tree house detectives used in their investigation in Segment 2. On the board or a transparency, make an outline of the steps. Identify these steps with the process of scientific inquiry. Tell the students that the process is not a step-by-step process.
6. Predict what will happen in Segment 3.

After Viewing

1. Discuss the questions that are asked at the end of the third segment of the video.
   - Will the change in material to the foam egg carton help the plane fly farther?
   - What's the most important force of flight?
   - What will help the tree house detectives win the contest?
2. "Biomimetics" expert Ben Anders studies how drag affects fish, birds, and insects. Compare and contrast the shark's fin and bird's wing to the wings of an airplane? Ask if there are any special features of the shark's fins and/or the bird's wings that help to reduce the amount of drag? How might this study be applied to airplane wings?
3. This segment introduces the students to control surfaces. Reinforce the terminology with a model or a class diagram to show the rudder (steering or turning), ailerons (rolling or banking), and elevator (up and down). Ask the students what combination of flight surfaces result in yaw, roll, and pitch?
4. Have your students investigate the control surfaces that existed on early airplanes such as the Wright Flyer. Have students list the problems that early aviators might have encountered because of their planes' designs?
5. Continue to guide the students in modifying and adding to the K-W-L chart. Predict what the tree house detectives will investigate next and the outcome of the contest.
6. Choose from the activities in this guide to help reinforce the concepts and objectives being emphasized in Segment 3.

Careers

test pilot
structural engineer
electronic classroom teacher
"biomimetics"

Resources

Kalman, Bobbie D.: *How Birds Fly.* Crabtree Publishing Co (1997), ISBN: 0865057680

Pallis, Jani Macari, Ph.D.: *The Big Book of Air and Space Flight.* McGraw-Hill (2000), ISBN: 0071348204

Web Sites

Plane Math
Provides on-line activities that will develop students' understanding of flight. Each of the activities includes the on-line lesson, an interview with the expert involved in the activity, group work that enhances problem-solving skills, and information addressing the national standards used and other possible extension ideas for the teacher or parent.
http://www.planemath.com/activities/pmactivities4.html

NASA Glenn Research Center
Test your skills in aerospace science by solving a weekly riddle or trivia question posted on the web by NASA Glenn Research Center.
http://www-psao.grc.nasa.gov/psaoquiz.html

Activities and Worksheets

In the Guide

On the Web

You can find the following activities on the Web at http://whyfiles.larc.nasa.gov.

Finding Your Center of Gravity
Weigh yourself and use a formula to find your own center of gravity.

Shapes of Nature
Create a mobile to compare and contrast shapes and designs of animals to airplanes.

Pitch, Roll, and Yaw
Demonstrate the six degrees of freedom of motion of flight

Fluttering Fun, Point of Balance

Purpose

To learn how an object's center of gravity can be changed.

Materials

butterfly pattern
construction paper
pencil with a flat eraser
modeling clay
scissors
paper clips
science journal

Procedure

1. Trace the butterfly pattern on construction paper.
2. Cut out the butterfly.
3. Mold a small amount of modeling clay into a ball and press on a flat surface.
4. Press a pencil into the clay with the eraser pointing up. See diagram 1.
5. Place the butterfly on top of the pencil's eraser. Move the butterfly around to find the point where it will balance.
6. Observe the position of the butterfly in relationship to the pencil eraser and record observations in science journal.
7. Attach one paper clip to each of the butterfly's front wing tips. Move the clips until you can get the butterfly to balance on the tip of its head. See diagram 2.
8. Observe and record observations in science journal.
9. Reposition the paper clips to the back wings and locate the new balancing point. Record observations in science journal.
10. Experiment with placing the paper clips in other locations on the butterfly and finding the balancing point.

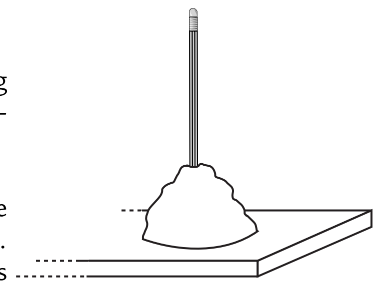


Diagram 1

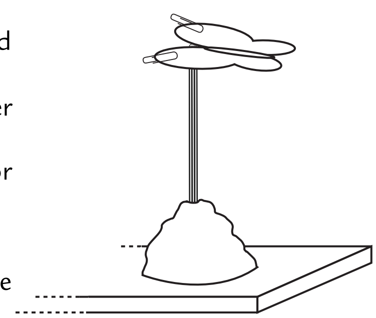


Diagram 2

Conclusion

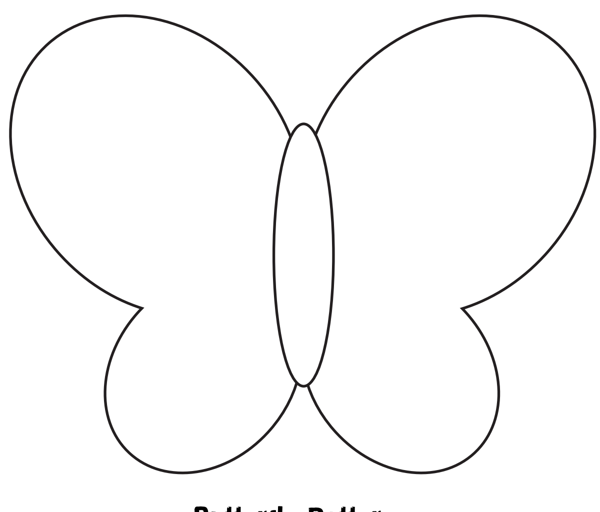
1. Explain why the balancing point (center of gravity) changed as you moved the paper clips.
2. What would happen if one wing of the butterfly were longer or shorter than the other wing?
3. Is it important to have a symmetrically shaped object for this experiment? Why or why not?

Extension

1. Use thicker paper or cardboard and see how it affects the center of gravity.
2. Dangle the paper clips from the wings instead of attaching them firmly.

Explanation

The place on the butterfly where it can be balanced is called the center of gravity. This balance points is the point where all the parts of the butterfly exactly balance each other. All objects can be balanced and thus have a center of gravity. Adding paper clips to the wings of the butterfly added weight to the wings. Weight is a measure of the force of gravity. The weight of the paper clips moved the center of gravity from the center of the butterfly's body to its head.



Butterfly Pattern

The Commotion of Motion

Purpose

To learn about Newton's first law of motion, which states that an object at rest will remain at rest, and an object in motion will remain in motion at constant velocity unless an unbalanced force acts upon it.

Materials (per group)

small toy car
30-cm X 45-cm piece of sturdy cardboard
clay
pencil
tape
2 books
science journal

Procedure

1. Make a ramp on a smooth, flat surface by propping one end of the cardboard on one edge of the book and taping the other edge of the cardboard to the flat surface. See diagram 1.
2. About 20 cm from the taped edge of the cardboard, horizontally tape a pencil in place. See diagram 2.
3. Using the clay, make a small clay figure shaped like a person.
4. Gently place the clay figure on the hood of the small toy car, being careful not to "press" the clay to the car.
5. Position the car with the clay figure at the raised end of the ramp. See diagram 3.
6. Release the car and observe the clay figure as the car rolls down the ramp and collides with the pencil. Record observations in your science journal.
7. Repeat by placing the clay figure in the car, behind the car, and pressed firmly on the hood of the car. Observe and record your observations in your science journal for each position.
8. Raise the cardboard to a higher angle by placing the second book on top of the first book and repeat the experiment with the various positions of the clay figure. Observe and record your observations in your science journal.

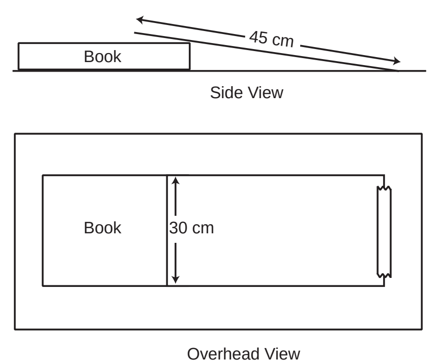


Diagram 1

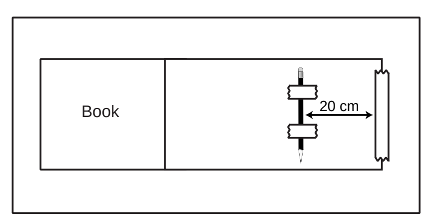


Diagram 2

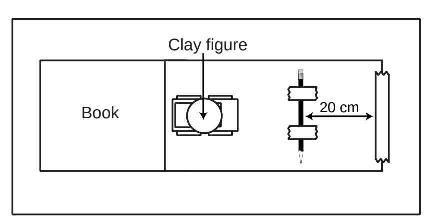


Diagram 3

Conclusion

1. What happened to the clay figure when it was on the hood of the car? Explain why.
2. Compare and contrast the other positions of the clay figure and explain the reactions.
3. Explain why it is important to wear a seat belt while riding in a vehicle.
4. What happened when you increased the angle of the cardboard? Why?

Explanation

Sir Isaac Newton called the tendency of objects to remain in motion or stay at rest inertia. Inertia is the property of matter that tends to resist any change in motion. The word inertia comes from the Latin word iners, which means "idle" or "lazy." You feel the effects of inertia when you ride in a car or an elevator. If your mom or dad is driving down the road at 50 mph and has to come to a sudden stop, your body will continue to move forward even though the car has stopped. That is inertia. When you are in an elevator and push the button to go down several floors, your body will continue to "fall" for a second or two after the elevator stops. This is inertia and it is what makes you feel like you "lost your stomach!"

What a Drag!

Purpose

To learn that shape affects the amount of drag on an object.

Materials

block of heavy foam
10 cm X 10 cm X 15 cm
30-cm wooden skewer
duct tape
metric ruler
scissors
wooden ruler with holes
flexible drinking straws
box fan with three speeds
clear tape
shape patterns (p. 45 and 46)
science journal
glue (optional)

Procedure

Teacher Prep

1. To make the drag stand (one per class), insert the wooden skewer 5 cm into the center of the foam block so that the measurement from the top of the wooden skewer to the bottom of the foam, where inserted, is 15 cm.
2. Measure and cut a 10 cm X 1 cm piece of duct tape.
3. Wrap the tape around the straw 2 cm from one end, making sure the tape is evenly wrapped and forms a level surface.
4. Slide the straw over the wooden skewer until it makes contact with the foam block. See diagram 1.
5. Place the box fan on a table or flat surface and plug in.
6. Loop a piece of duct tape to make a double-sided tape. Attach the duct tape to the bottom of the foam block.
7. Measure 1 m from the front center of the box fan and place drag stand at that point, making sure it is secured to the surface. See diagram 2.
8. To assemble the drag arm, insert a flexible straw into the outer holes of a wooden ruler an equal distance from the center hole (pivot point).
9. Secure straws to the ruler by placing two small pieces of duct tape around the top of the straw. See diagram 3.
10. Cut out the shapes (pp. 45 and 46), bend on the dotted lines, and tape the edges together (cone, cube, tetrahedron, and pyramid). Note: Depending on the abilities of your students, this step may be completed by the students.
11. Assess your students' knowledge of drag by asking them:
    What is drag?
    How would shape affect drag?
    How does drag affect an airplane's ability to fly?

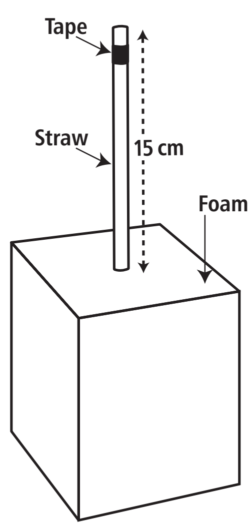


Diagram 1

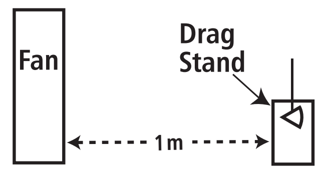


Diagram 2

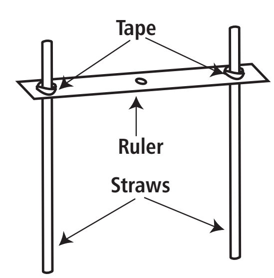


Diagram 3

What a Drag! (continued)

12. Have students copy this Data Chart in their science journals.

Data Chart

Shape	Cone	Cube	Pyramid	Tetrahedron
Cone				
Cube				
Pyramid				
Tetrahedron				

Note: Discuss a matrix and why some of the spaces in the chart will be either duplicated or not used. For example, you will not test a cone and a cone because they are the same shape.

13. Beginning with the cone and the cube, attach shapes to the bottom of each straw using clear tape. See diagram 4.
14. Place the drag arm onto the drag stand by placing the ruler over the straw on the drag stand. See diagram 5.
15. Ask the students to predict which shape will have the most drag. Record their predictions in their science journals.
16. Turn the fan on low speed.
17. Observe and note which shape moves closer to the fan. This shape will be the one that has the least amount of drag. Record the shape that had the least amount of drag on Data Chart.
18. Compare student predictions with the results. Discuss.
19. Repeat steps 12-17 with the following combination of shapes:
    cone and pyramid
    cone and tetrahedron
    cube and pyramid
    cube and tetrahedron
    pyramid and tetrahedron
20. Using the data from the Data Chart, ask the students which shape had the least amount of drag (the shape that appears in the chart the most often).

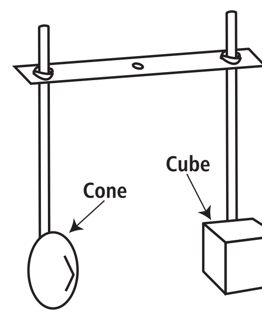


Diagram 4

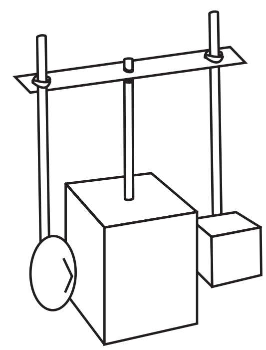


Diagram 5

Conclusion

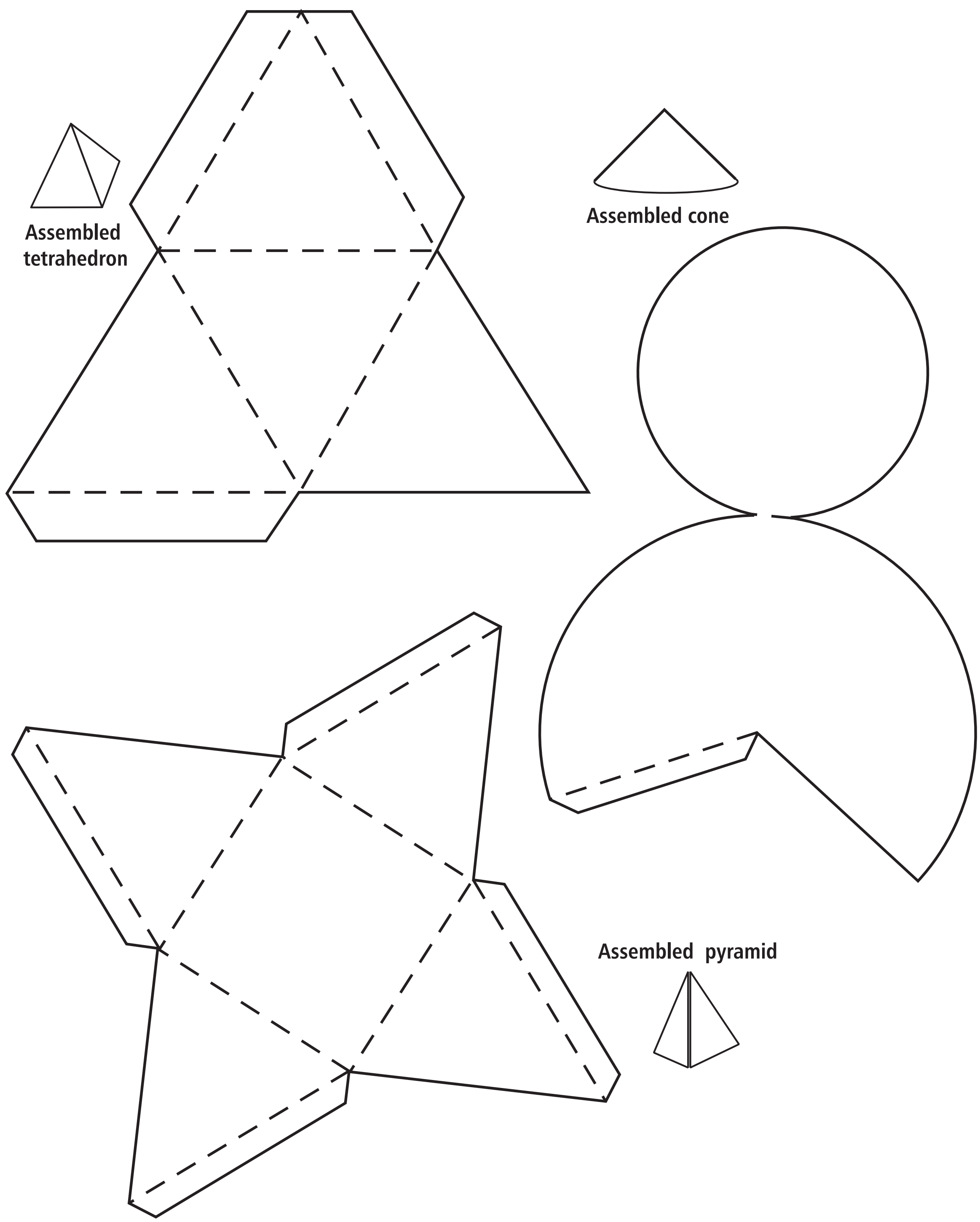
1. Does shape affect drag? Why or why not?
2. Would changing the size of the shape affect the outcome of this experiment? Why or why not?

Extensions

1. Design a vehicle for NASA, determining which shape would have the least drag? Have students draw a picture of their vehicle and justify their design.
2. Discuss how the shape of an object would be affected by drag in space.
3. Cut out various sized squares of cardboard (10 cm, 20 cm, 40 cm, and 60 cm). Have students stand in front of the box fan holding each square one at a time to feel how the size of an object affects drag. The larger squares should "push" on the students more than the smaller squares. Discuss why.

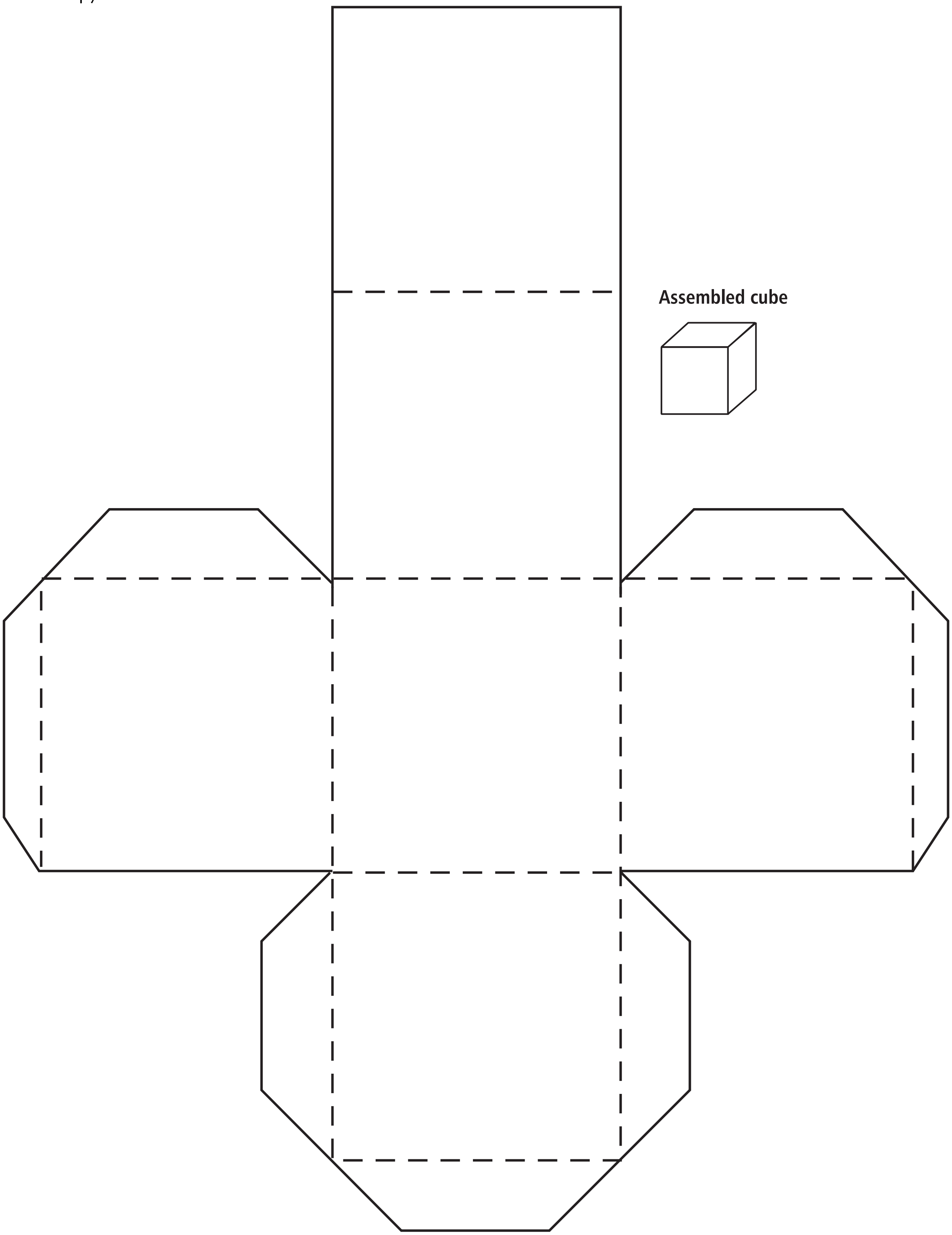
What a Drag! (patterns)

Photocopy at 125%.



What a Drag! (Patterns)

Photocopy at 125%.



Assembled cube

On Nature's Authority

Purpose

To observe flight in nature.

Materials

assortment of leaves, petals, and seeds of different shapes and sizes from various plants
science journal
pencil

Procedure

1. In your science journal, draw a chart similar to the one below with space for 10 or more leaves, petals, or seeds.

Name or Picture of Leaf, Petal, or Seed	Maneuvers		
	Drop	Toss	Twirl

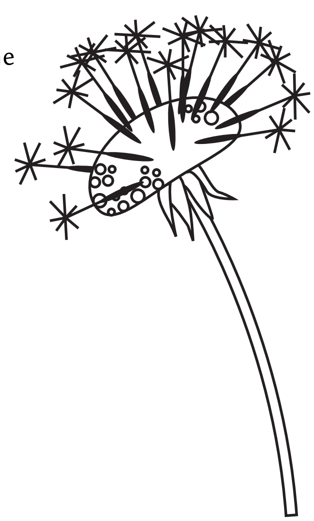
2. Gather an assortment of leaves, petals, and seeds.
3. Decide how to sort your leaves (by color, shape, size, and so on) and make piles as you sort.
4. Choose a pile and a leaf from that pile. Write the name or draw a picture of the leaf.
5. Drop the leaf and record how it responded after it was dropped.
6. Toss the leaf and record how it responded after it was dropped.
7. Twirl the leaf and record how it responded after it was dropped.
8. Continue dropping, tossing, and twirling the remainder of the leaves. Observe and record your observations.
9. Discuss how each leaf responded. Did it glide, float, or just drop to the ground?
10. Re-sort your leaves according to the new data that you have obtained.

Conclusion

1. How did the piles differ from the original sorting and the second sorting?
2. What were some characteristics of the leaves, petals, or seeds that glided?
3. Why did some just drop to the ground?
4. What would happen if you dropped two identical leaves but one had the stem removed? Explain.

Extensions

1. Toss a fresh leaf and compare its response to a leaf of the same kind that has been dried.
2. Build a glider using the various leaves, petals, and seeds.



Bugs O'Copter

Purpose

To practice controlling variables to determine rate of decent.

Materials

scissors
4 Bugs O'Copters
paper clips (for weights)
stopwatch
meter stick
science journal

Procedure

1. You will need 4 Bugs O'Copters. To make Bugs ready to fly, cut pattern (p. 49) along solid lines and fold along dotted lines. Fold flap A backwards, flap B forward, flap C backward, and flap D forward.
2. Label your Bugs 1, 2, 3, and 4.
3. Set stopwatch to zero. Note: You will start the stopwatch when your partner lets go of Bugs and stop the stopwatch when Bugs hits the ground.
4. Working with your partner, hold Bugs #1 1.5 m (150 cm) from the floor and drop while your partner times its descent. See diagram 1.
5. Record time in your science journal.
6. To determine the average rate of descent, repeat Steps 4-5 for two more trials and average your data.
7. Calculate the rate of descent by using the formula R = d/t (Rate = distance divided by time) and record in your science journal.

____________	=	____________	÷	____________
avg. rate of decent		distance (150 cm)		time (# seconds)

8. On Bugs # 2, change a variable by bending or folding a portion of each ear and repeat steps 3-7.
9. Change the variable of distance by decreasing the height from the floor to 1 m (100 cm) and repeat steps 3-7 for Bugs #1 and #2.
10. Add 1-3 paper clips to Bugs #3 and repeat steps 3-7.
11. Determine a variable of your choice to change and repeat steps 3-7 on Bugs #4.
12. Create a graph showing the rate of descent for each variable tested.

Diagram 1

Conclusion

1. Did all Bugs drop the same? Why or why not?
2. What were the variables that you changed in each experiment?
3. Why is it important to keep all other variables constant during an experiment?
4. Calculate the average speed for all the Bugs.
5. Compare your Bugs O'Copter with other leaves, animals, or seeds in nature.

Extension

1. To determine the number of rotations the Bugs O'Copter makes as it descends, (1) tape a piece of cassette ribbon (100 cm) to the bottom of Bugs, (2) stand on the loose end of the ribbon and pull Bugs up so that there are no twists in the ribbon, and (3) drop Bugs as usual. Count the number of twists in the ribbon to determine the number of rotations. Vary the height. See diagram 2.

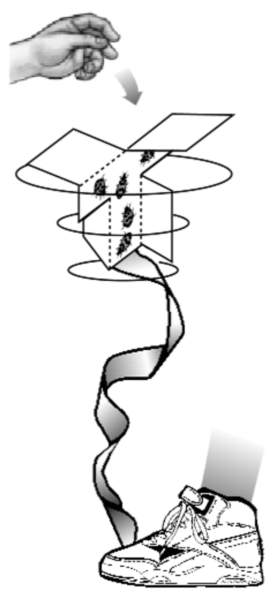


Diagram 2

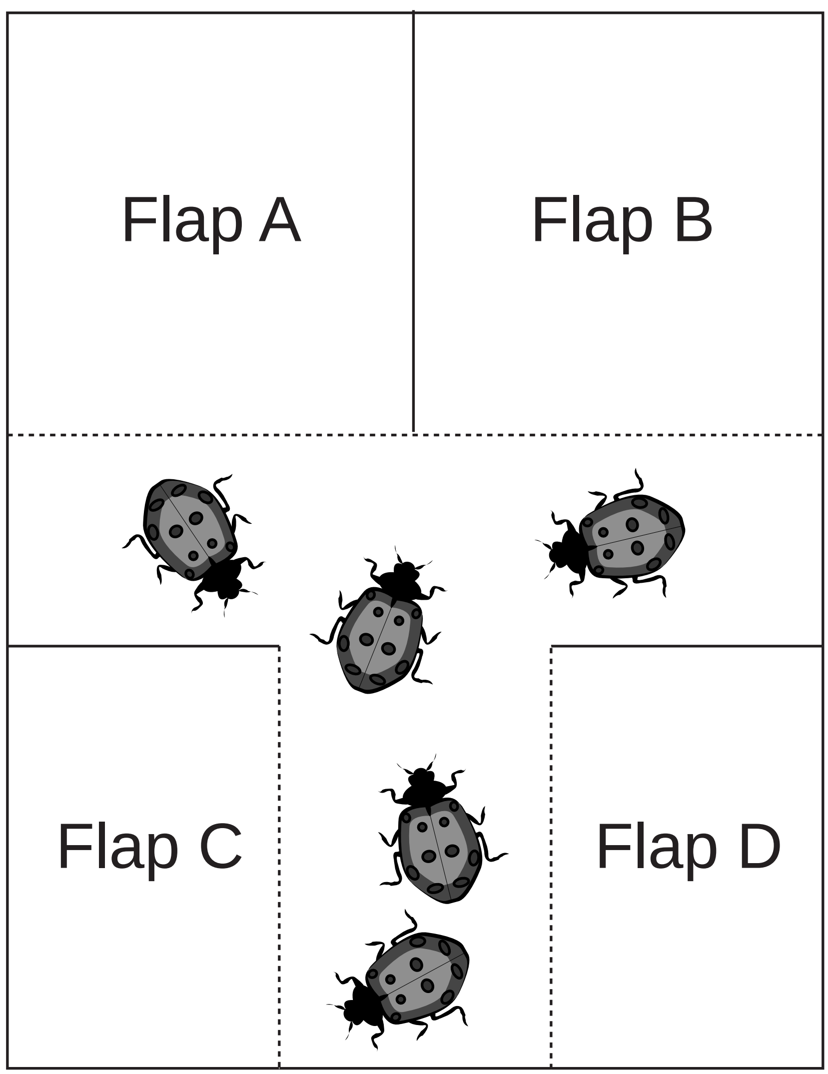
Bugs O'Copter (continued)

2. After the bug is dropped, construct a bar graph that shows the relationship between the height and the number of twists.
3. Experiment with various weights of paper and graph the results.
4. Have students determine relationships between the weight, height of launch, shape, and the length of the "blades."
5. Have students determine if the "blades" turn in a clockwise or counterclockwise direction.
6. Compare the flight of Bugs to that of a maple seed or dandelion.

Explanation

Your Bugs O'Copter spiraled down, demonstrating its natural gliding flight that is similar to the leaves, petals, and seeds in nature. It changed speed and maybe even direction when you changed the variables. As you observe nature, you will see that no two species of leaves, petals, or seeds are exactly the same. Nature has changed the variables so they all have their own unique characteristics that suit them best for their environment. When conducting flight research, scientists observe the characteristics of objects in nature and how they glide. Scientists will sometime try to duplicate their observations and then change various variables to determine what would work best for a glider, plane, or space shuttle.

Pattern



Falling Bridges, Structures and Materials

Purpose

To learn how different materials vary in strength.

Materials

miniature marshmallows
uncooked spaghetti
drinking straws
craft sticks
glue
tape
2-liter bottle filled with water for testing bridge
science journal and pencil
2 books

Procedure

1. In your science journal, brainstorm ideas for the design of a bridge that spans a distance of 30 cm between two books, will hold the weight of a 2-liter bottle of liquid (about 5 lb), and is constructed only from the materials provided.
2. Discuss with your group the pros and cons of each design.
3. Choose a design, gather the necessary materials, and construct the bridge.
4. Once the bridge is complete, use the 2-liter bottle to test your bridge. If the bridge collapses, rethink your design and build again if time permits.
5. The group who builds (in the shortest amount of time) a bridge that will hold the bottle wins the Structures Award!

Conclusion

1. Did your bridge hold the 2-liter bottle of water? Explain why or why not.
2. How could you make your bridge structurally stronger?
3. Why would an aeronautical or aerospace engineer be concerned about the strength of the materials used to make planes and space vehicles?
4. Would an aeronautical engineer want a heavy material? Why or why not?

Extension

1. Have a contest to see whose bridge can hold the most weight.
2. Add construction cost to the contest by placing a dollar value on each piece. For example, a marshmallow could cost $100 and each piece of spaghetti $25, and so on. Try to get the strongest structure for the least amount of money or set a budget and see who can finish on or under budget.
3. Using a balance to weigh the bridges, see which bridge is the lightest but holds the most weight.

Explanation

In aeronautical and aerospace engineering, structures and materials is a very important field. Vehicles designed and manufactured for flight must be strong but lightweight. Vehicles that fly are subjected to great amounts of stress during takeoff and landing, so they must be strong. However, to be fuel efficient, they must also be lightweight. The research performed at NASA Langley Research Center, featured in the video, discusses composites and smart materials that will make lighter, yet stronger materials for future aviation vehicles.

Answer Key

In the Guide

Fluttering Fun

1. The center of gravity changed as the paper clips were moved because the weight was redistributed.
2. If one wing was longer or shorter than the other wing, the center of gravity would be different. The center of gravity would have to shift to balance the difference in weight from one side to the other.
3. No, it is not important to have a symmetrically shaped object. However, a symmetrically shaped object makes it easier to find the center of gravity because the weight is evenly distributed.

The Commotion of Motion

1. The clay figure kept going forward when the toy car was forced to stop because the pencil blocked its path. Since the clay figure was not secured to the car, the clay figure continued in motion even though the car stopped. This is inertia.
2. If the clay figure is secured in or on the car, it will stop with the car. Depending on the size of the car and the figure, the figure may move forward a small amount even though it is secured.
3. It is important to wear a seat belt while riding in a car so that your body does not continue to move forward and into the windshield if the car should have to come to a sudden stop.
4. When the angle of the cardboard was increased, the speed of the car was increased. This increase in speed caused the clay figure to fly even farther. The greater the speed, the greater the inertia.

What a Drag!

1. Yes, shape affects drag. A shape that is "aerodynamic" is more streamlined and does not "catch" as much wind as a shape that is not "aerodynamic."
2. If all shapes were increased equally in size, the change would not affect the outcome of the experiment. Changing the size of one or two of the objects would change the surface area, and that change would be a variable that would affect the outcome of the experiment.

On Nature's Authority

1. Answers will vary.
2. Answers will vary but might include characteristics such as a curved surface, lightweight, and smooth surface.
3. Answers will vary but might include that the object had too heavy or too small a surface area to glide.
4. If you dropped two identical leaves with the stem removed from one, the heavier one would fall at a faster rate than the one without the stem.

Bugs O'Copter

1. No, all Bugs did not drop the same because the variables were changed. Variables included adding weight, repositioning flaps, and changing the height from which it was dropped. All these factors contributed to slight changes in the way Bugs would fall as it was dropped.
2. For Bugs 2, the variable was that a portion of each ear was folded. For Bugs 3, the variable was the added weight. For Bugs 4, answers will vary depending on student's choice.
3. In any experiment, a scientist attempts to test one variable and only one variable at a time to ensure that the results of the experiment are due to the variable being tested and not some hidden factor.

4-5. Answers will vary.

Falling Bridges

1. Answers will vary.
2. Answers will vary.
3. An aeronautical or aerospace engineer wants to make materials strong so they can endure the stress of flight. They would want to make the materials lightweight so that they will save on fuel consumption.
4. An aeronautical engineer would not want a heavy material because it would take too much fuel to lift off and fly the plane.

On the Web

Finding Your Center of Gravity

1. The center of gravity should be different for both students because they are of various sizes and weights.

Shapes of Nature

1. Answers will vary.
2. Scientists would want to study the wings or fins of an animal to try to improve on airplane design. Nature is the ultimate flying authority, and we can learn much by observing animals that fly or swim.
3. Various airplanes are designed for different tasks. A fighter plane, such as an F-18, would have very different shaped wings than a cargo or passenger plane.
4. Various birds use their wings for different functions. A bird such as an eagle needs to glide and swoop quickly to catch live prey, while a robin eats mostly insects and seeds.

Pitch, Roll, and Yaw

1. Pitch is located on the lateral axes. Roll is located on the longitudinal axes.
2. Yes, this is the way that a pilot maneuvers a plane; however, he controls the degree to which the plane pitches, rolls, or yaws by using his ailerons, rudder, and elevators.